

Hadron Molecules^{*}

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Abstract We discuss a possible interpretation of the open charm mesons $D_{s0}^*(2317)$, $D_{s1}(2460)$ and the hidden charm mesons $X(3872)$, $Y(3940)$ and $Y(4140)$ as hadron molecules. Using a phenomenological Lagrangian approach we review the strong and radiative decays of the $D_{s0}^*(2317)$ and $D_{s1}(2460)$ states. The $X(3872)$ is assumed to consist dominantly of molecular hadronic components with an additional small admixture of a charmonium configuration. Determining the radiative ($\gamma J/\psi$ and $\gamma\psi(2s)$) and strong ($J/\psi 2\pi$ and $J/\psi 3\pi$) decay modes we show that present experimental observation is consistent with the molecular structure assumption of the $X(3872)$. Finally we give evidence for molecular interpretations of the $Y(3940)$ and $Y(4140)$ related to the observed strong decay modes $J/\psi + \omega$ or $J/\psi + \phi$, respectively.

Key words charm mesons, hadronic molecule, strong and radiative decay

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1 Introduction

The complexity of hadronic mass spectra allows for the possibility that existing and newly observed hadrons can possibly be interpreted as hadronic molecules. Such an interpretation is possible when the mass of the observed meson lies close to or slightly below the threshold of a corresponding hadronic pair. In the following we focus on some of the candidates in the heavy meson sector which are discussed and considered as such hadronic bound states.

The $X(3872)$ is one of the peculiar new meson resonances which was discovered during the last years^[1] and where its properties cannot be simply explained in the context of conventional constituent quark models. In the molecular approaches, the earliest given in Refs. [2, 3], it is argued that the $X(3872)$ can be identified with a weakly-bound hadronic molecule whose constituents are D and D^* mesons. This natural interpretation is due to the fact that its mass is very close to the $D^0\bar{D}^{*0}$ threshold and hence is in analogy to the deuteron — a weakly-bound state of proton and neutron.

In the open charm sector the scalar $D_{s0}^*(2317)$ and axial $D_{s1}(2460)$ mesons could be candidates for

a scalar DK and a axial D^*K molecule because of a relatively small binding energy of ~ 50 MeV. These states were discovered and confirmed just a few years ago by the Collaborations BABAR^[4], CLEO^[5] and Belle^[6]. The simplest interpretation of these states is that they are the missing $j_s = 1/2$ (the angular momentum of the s -quark) members of the $c\bar{s}$ $L = 1$ multiplet. However, this standard quark model scenario is in disagreement with experimental observation since the $D_{s0}^*(2317)$ and $D_{s1}(2460)$ states are narrower and their masses are lower when compared to theoretical expectations (see e.g. discussion in Ref. [7]).

The CDF Collaboration recently reported evidence for a narrow near-threshold structure, termed the $Y(4140)$ meson, in the $J/\psi\phi$ mass spectrum in exclusive $B^+ \rightarrow J/\psi\phi K^+$ decays with the mass $m_{Y(4140)} = 4143.0 \pm 2.9(\text{stat}) \pm 1.2(\text{syst})$ MeV and natural width $\Gamma_{Y(4140)} = 11.7^{+8.3}_{-5.0}(\text{stat}) \pm 3.7(\text{syst})$ MeV^[8]. As already stressed in^[8], the new structure $Y(4140)$, which decays to $J/\psi\phi$ just above the $J/\psi\phi$ threshold, is similar to the previously discovered $Y(3940)$ ^[9, 10], which decays to $J/\psi\omega$ near this respective threshold. Both observed states, $Y(4140)$ and $Y(3940)$, are well above the threshold for open charm decays. A con-

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ventional $c\bar{c}$ charmonium interpretation is disfavored, since open charm decay modes would dominate, while the $J/\psi\phi$ or $J/\psi\omega$ decay rates are essentially negligible [8, 11]. This could be a signal for nonconventional structure of these Y states.

In the following we give a compact overview of our recent calculations related to the strong and electromagnetic decay properties of the $D_{s0}^*(2317)$, $D_{s1}(2460)$, $X(3872)$, $Y(3940)$ and $Y(4140)$ mesons interpreted as hadron molecules. Details can be found in the related publications [12–21] on this topic.

2 The method

We first briefly discuss the formalism behind the study of hadronic molecules. As an example we consider the $D_{s0}^{*\pm}(2317)$ meson as a bound state of a D and a K meson. We use the current results for the quantum numbers of isospin, spin and parity: $I(J^P) = 0(0^+)$ and mass $m_{D_{s0}^*} = 2.3173$ GeV [1]. Our framework is based on an effective interaction Lagrangian describing the coupling between the $D_{s0}^*(2317)$ meson and their constituents - D and K mesons:

$$\mathcal{L}_{D_{s0}^*}(x) = g_{D_{s0}^*} D_{s0}^{*-}(x) \int dy \Phi_{D_{s0}^*}(y^2) \cdot D^T(x + w_K y) K(x - w_D y) + \text{H.c.} \quad (1)$$

where D and K are the meson doublets and $w_{ij} = \frac{m_i}{m_i + m_j}$ is a kinematic variable. The correlation function $\Phi_{D_{s0}^*}$ characterizes the finite size of the $D_{s0}^*(2317)$ meson as a (DK) bound state and depends on the relative Jacobi coordinate y with x being the center of mass (CM) coordinate. The Fourier transform of the correlation function is $\tilde{\Phi}_{D_{s0}^*}(p_E^2) \doteq \exp(-p_E^2/\Lambda_{D_{s0}^*}^2)$, where p_E is the Euclidean Jacobi momentum. Here $\Lambda_{D_{s0}^*}$ is a size parameter, which parametrizes the distribution of D and K mesons inside the D_{s0}^* molecule. The $D_{s0}^* DK$ coupling constant $g_{D_{s0}^*}$ is determined by the compositeness condition [22, 23], which implies that the renormalization constant of the hadron wave function is set equal to zero: $Z_{D_{s0}^*} = 1 - \Sigma'_{D_{s0}^*}(m_{D_{s0}^*}^2) = 0$, where $\Sigma'_{D_{s0}^*}$ is the derivative of the D_{s0}^* meson mass operator. The effective Lagrangian is the basis for the study of the decay properties of the hadronic molecules. It defines the coupling of the molecule to its constituents but also supplies the hadron loop connected to the final state particles considered. The interaction of the constituents with external particles is further described by effective Lagrangians either adjusted by data or by theory (as for example by heavy hadron chiral perturbation theory [24, 25]

(HHCHPT)). Further details of this procedure can be found in Refs. [12, 21].

3 Strong and radiative decays of $D_{s0}^*(2317)$ and $D_{s1}(2460)$

For the $D_{s0}^*(2317)$ we consider a possible interpretation as a hadronic molecule - a bound state of D and K mesons. Using an effective Lagrangian approach we calculated the strong $D_{s0}^* \rightarrow D_s \pi^0$ and radiative $D_{s0}^* \rightarrow D_s^* \gamma$ decays [14]. A new impact related to the DK molecular structure of the $D_{s0}^*(2317)$ meson is that the presence of $u(d)$ quarks in the D and K mesons gives rise to a direct strong isospin-violating transition $D_{s0}^* \rightarrow D_s \pi^0$ (see Fig.1) in addition to the decay mechanism induced by $\eta - \pi^0$ mixing considered previously (see Fig.2).

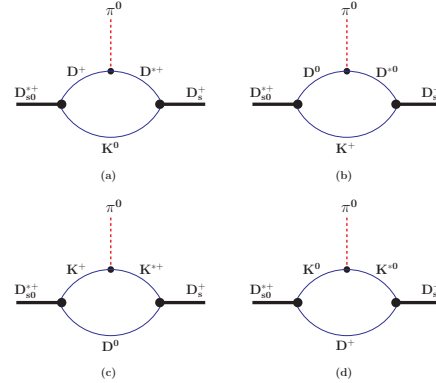


Fig. 1. Direct isospin-violating transition for $D_{s0}^* \rightarrow D_s \pi^0$

We show [14] that the direct transition dominates over the $\eta - \pi^0$ mixing transition in the $D_{s0}^* \rightarrow D_s \pi^0$ decay.

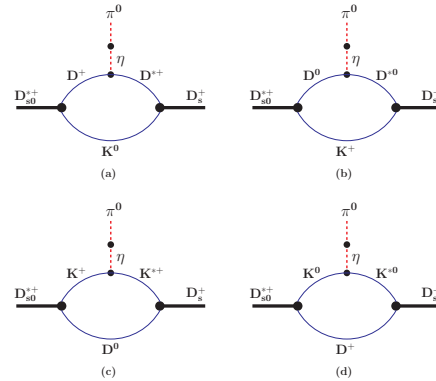


Fig. 2. $\eta - \pi^0$ mixing transition for $D_{s0}^* \rightarrow D_s \pi^0$

The radiative transition $D_{s0}^{*+} \rightarrow D_s^{*+} \gamma$ is generated by the loop diagrams of Fig.3, where the last graphs have to be included to guarantee full gauge invariance for the case of a non-local vertex.

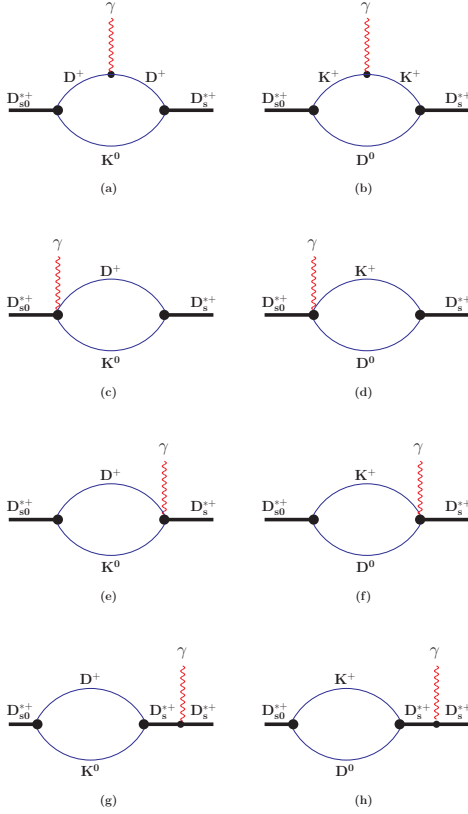


Fig. 3. Radiative transition $D_{s0}^{*+} \rightarrow D_s^{*+} \gamma$

The other strong coupling vertices are fixed by HHCHPT or by data, for full details see Ref. [14]. Similar graphs apply for the strong and radiative transitions of the $D_{s1}(2460)$ interpreted in the present framework as a D^*K hadronic molecule [13]. Results for the strong decays are

$$\begin{aligned} \Gamma(D_{s0}^* \rightarrow D_s \pi^0) &= 47 - 112 \text{ keV}, \\ \Gamma(D_{s1} \rightarrow D_s^* \pi^0) &= 50 - 79 \text{ keV}, \end{aligned} \quad (2)$$

while for the radiative modes we have

$$\begin{aligned} \Gamma(D_{s0}^* \rightarrow D_s^* \gamma) &= 0.47 - 0.63 \text{ keV}, \\ \Gamma(D_{s1} \rightarrow D_s \gamma) &= 2.7 - 3.7 \text{ keV}. \end{aligned} \quad (3)$$

The variation in results reflects the uncertainty in the vertex function. The corresponding ratios of rates with

$$\begin{aligned} R_{D_{s0}^*} &= \Gamma(D_{s0}^* \rightarrow D_s^* \gamma) / \Gamma(D_{s0}^* \rightarrow D_s \pi) = 0.01 \\ R_{D_{s1}} &= \Gamma(D_{s1} \rightarrow D_s \gamma) / \Gamma(D_{s1} \rightarrow D_s^* \pi) = 0.05 \end{aligned} \quad (4)$$

satisfy qualitatively the present experimental results of $R_{D_{s0}^*} \leq 0.059$ and $R_{D_{s1}} = 0.44 \pm 0.09$ [1]. Hence from the present observation of the radiative and strong decays of the D_{s0}^* and D_{s1} an interpretation as DK and D^*K hadron molecules seems feasible.

In Ref. [15] we further investigated the weak decays $B \rightarrow D^{(*)} + D_{s0}^*(D_{s1})$, where full consistency with present data is achieved. This further strengthens the presented molecular picture. We also give predictions [21] for the weak decays involving $f_0(980)$, which serves as a further indicator for this structure interpretation.

4 Decay analysis of $X(3872)$

The $X(3872)$ with quantum numbers $J^{PC} = 1^{++}$ is considered as a composite state containing both molecular hadronic and a $c\bar{c}$ component. We recently showed [18] that slight binding of the DD^* system can be achieved in a full meson-exchange model. Following Refs. [17, 26] we consider the $X(3872)$ state as a superposition of the dominant molecular $D^0 D^{*0}$ component, of other hadronic configurations— $D^\pm D^{*\mp}$, $J/\psi\omega$, $J/\psi\rho$, as well as of the $c\bar{c}$ charmonium configuration as

$$\begin{aligned} |X(3872)\rangle &= \cos\theta \left[\frac{Z_{D^0 D^{*0}}^{1/2}}{\sqrt{2}} (|D^0 \bar{D}^{*0}\rangle + |D^{*0} \bar{D}^0\rangle) + \frac{Z_{D^\pm D^{*\mp}}^{1/2}}{\sqrt{2}} (|D^+ D^{*-}\rangle + |D^- D^{*+}\rangle) + Z_{J/\psi\omega}^{1/2} |J/\psi\omega\rangle + Z_{J/\psi\rho}^{1/2} |J/\psi\rho\rangle \right] \\ &+ \sin\theta c\bar{c}. \end{aligned} \quad (5)$$

Here θ is the mixing angle between the hadronic and the charmonium components: $\cos^2\theta$ and $\sin^2\theta$ represent the probabilities to find a hadronic and charmonium configuration, respectively, for the normalization

$$Z_{D^0 D^{*0}} + Z_{D^\pm D^{*\mp}} + Z_{J/\psi\omega} + Z_{J/\psi\rho} = 1. \quad (6)$$

For comparison with data we employ values for $Z_{D^0 D^{*0}}$, $Z_{D^\pm D^{*\mp}}$, $Z_{J/\psi\omega}$ and $Z_{J/\psi\rho}$ as derived in a po-

tential model. For example, for a binding energy $\epsilon_{D^0 D^{*0}} = m_{D^0} + m_{D^{*0}} - m_X = 0.3 \text{ MeV}$ the estimate of Ref. [26] provides

$$\begin{aligned} Z_{D^0 D^{*0}} &= 0.92, \quad Z_{D^\pm D^{*\mp}} = 0.033, \\ Z_{J/\psi\omega} &= 0.041, \quad Z_{J/\psi\rho} = 0.006. \end{aligned} \quad (7)$$

The coupling of the X to its constituents, once the amplitudes of Eq. (7) are chosen, are determined

again by the compositeness condition ^[16, 17, 19].

A new measurement by the *BABAR* Collaboration gives clear evidence for a strong radiative decay mode involving the $\psi(2S)$ ^[27]. They indicate the measured ratio of

$$\frac{\mathcal{B}(X(3872) \rightarrow \psi(2S)\gamma)}{\mathcal{B}(X(3872) \rightarrow J/\psi\gamma)} = 3.5 \pm 1.4. \quad (8)$$

As known from previous calculations in the molecular approach the radiative decay width of the $X(3872) \rightarrow \psi(2S)\gamma$ is always smaller than the one involving $J/\psi\gamma$. It is therefore expected that the ratio of Eq. (8) gives some constraint on a possible charmonium component in the $X(3872)$.

In Fig.4 we display the diagrams relevant for the radiative decays $X \rightarrow J/\psi\gamma$ and $X \rightarrow \psi(2S)\gamma$. The last diagram of Fig.4 which is generated by the $J/\psi V$ ($V = \rho, \omega$) component of the $X(3872)$ only contributes to the $J/\psi\gamma$ final state.

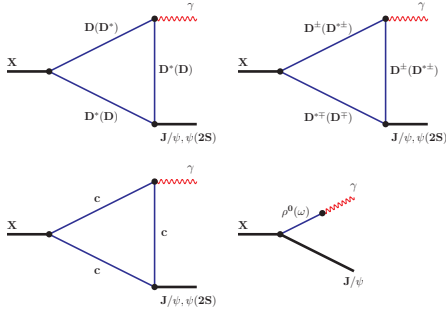


Fig. 4. Diagrams contributing to the radiative transitions $X(3872) \rightarrow J/\psi + \gamma$ and $X(3872) \rightarrow \psi(2S) + \gamma$.

Results ^[16] for the radiative decay modes involving the hadronic components of the $X(3872)$ are contained in Table 1. The value of the binding energy is set to 0.3 MeV with the probabilities taken from Eq. (7).

Table 1. Radiative decays of hadronic components.

Hadronic config.	$\Gamma(X(3872) \rightarrow \gamma J/\psi, \gamma \psi(2S))$ keV
DD^*	60 - 120 (J/ψ) 0.3 ($\psi(2S)$)
$J/\psi V$	6 (J/ψ) 0 ($\psi(2S)$)
DD^* and $J/\psi V$	30 - 65 (J/ψ) 0.3 ($\psi(2S)$)

The inclusion of the $J/\psi V$ components in the structure of the $X(3872)$ leads to a decrease in the $X \rightarrow J/\psi\gamma$ rate because $\psi(2S)V$ components are absent in the $X(3872)$. Note that taking into account the hadronic components only the ratio of Eq. (8) cannot be explained. If no $c\bar{c}$ component is present in the $X(3872)$ the decay width for $J/\psi\gamma$ is about

60 keV and is much larger than the one for the $\psi(2S)\gamma$ channel (about 0.3 keV). Inclusion of a charmonium component in the $X(3872)$ configuration leads to the results of Fig. 5 indicating the radiative decay widths in dependence on the $c\bar{c}$ admixture.

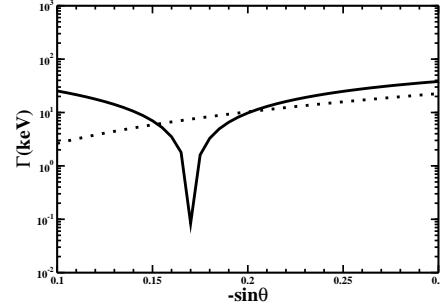


Fig. 5. Radiative decay widths of the $X(3872)$. Solid and dotted curves are the results for the transitions $X \rightarrow J/\psi\gamma$ and $X \rightarrow \psi(2S)\gamma$, respectively.

A small admixture of a $c\bar{c}$ component is essential to reproduce the large measured value for R_{2S} ^[16]. This feature is due to the destructive interference between the $J/\psi\gamma$ decay amplitudes arising from the $c\bar{c}$ and the hadronic components. For mixing values of about $\sin\theta \approx -0.16$ in the case of $\epsilon = 0.3$ MeV the decay width for $\psi(2S)\gamma$ may exceed the one of $J/\psi\gamma$ and a consistent explanation for the observed ratio R_{2S} is obtained.

To get estimates ^[17] for the decay widths of $X(3872) \rightarrow J/\psi + h$ with $h = \pi^+\pi^-\pi^0, \pi^+\pi^0, \pi^0\gamma, \gamma$ we use the results of Ref. [28], which are based on the assumption that these decays proceed through the processes X to $J/\psi\omega$ and $J/\psi\rho$. Here we estimate ^[17] both short and long-distances effects only for the $X \rightarrow \gamma J/\psi$ decays using our previous result, while the $X \rightarrow J/\psi + h$ decays only take into account short-distance effects. Results for the J/ψ decay modes are given in Table 2.

Table 2. Properties of $X \rightarrow J/\psi + h$ decays.

Numbers in brackets are valid for explicit values for $Z_{J/\psi\rho}$ and $Z_{J/\psi\omega}$ of Eq. (7). Data for ratios are from Refs. [27, 29].

Quantity	Nonlocal case
$\Gamma(X \rightarrow J/\psi\pi^+\pi^-), \text{ keV}$	$9.0 \times 10^3 Z_{J/\psi\rho} (54.0)$
$\Gamma(X \rightarrow J/\psi\pi^+\pi^-\pi^0), \text{ keV}$	$1.38 \times 10^3 Z_{J/\psi\omega} (56.6)$
$\Gamma(X \rightarrow J/\psi\pi^0\gamma), \text{ keV}$	$0.23 \times 10^3 Z_{J/\psi\omega} (9.4)$
$\frac{\Gamma(X \rightarrow J/\psi\pi^+\pi^-\pi^0)}{\Gamma(X \rightarrow J/\psi\pi^+\pi^-)}$ $= 1.0 \pm 0.4 \pm 0.3$	1.05
$\frac{\Gamma(X \rightarrow J/\psi\gamma)}{\Gamma(X \rightarrow J/\psi\pi^+\pi^-)}$ $= 0.14 \pm 0.05; 0.33 \pm 0.12$	0.10

Present data for the ratio of rates $\frac{\Gamma(X \rightarrow J/\psi \pi^+ \pi^- \pi^0)}{\Gamma(X \rightarrow J/\psi \pi^+ \pi^-)}$ indicate a strong isospin violating $J/\psi \pi^+ \pi^- \pi^0$ decay mode. Similarly, the measured ratio $\frac{\Gamma(X \rightarrow J/\psi \gamma)}{\Gamma(X \rightarrow J/\psi \pi^+ \pi^-)}$ points to a large radiative decay channel. Both ratios of rates can be fully reproduced in the molecular picture. Note that all the decay channels considered so far are fed by the subleading $J/\psi \omega$, $J/\psi \rho$ and $c\bar{c}$ components. To work out the influence of the leading molecular components we consider the hadronic $X \rightarrow \chi_{cJ} + (\pi^0, 2\pi)$ and $X \rightarrow J/\psi + (2\pi, 3\pi)$ decays^[17]. Here the values of $J = 0, 1, 2$ correspond to the $J^P = 0^+, 1^+, 2^+$ quantum numbers of the charmonium states. Because of the dominance of the $D^0 D^{*0}$ component in the transitions of X into charmonium states χ_{cJ} and pions we estimate these decays using only this component. The two-body decays are described by the $(D^0 D^{*0})$ loop diagram shown in Fig.6.

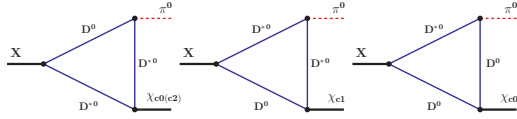


Fig. 6. Diagrams contributing to the hadronic transitions $X(3872) \rightarrow \chi_{cJ} + \pi^0$.

Inclusion of the charged $(D^\pm D^{*\mp})$ loops gives a further correction to the decay widths. The possible couplings of $D(D^*)$ mesons to pions and charmonia states is taken from HHChPT. Similar graphs apply for the three-body decay modes. Results for the hadronic decays involving the neutral $(D^0 D^{*0})$ component only and the full results are indicated in Table 3.

Table 3. Properties of $X \rightarrow \chi_{cJ} + n\pi$ decays. Here $Z_D \equiv Z_{D^0 D^{*0}}$.

Quantity	$D^0 D^{*0}$ loop	$D^0 D^{*0} + D^- D^{*+}$
$\Gamma(X \rightarrow \chi_{c0} + \pi^0)$, keV	41.1 Z_D (37.8)	61.0
$\Gamma(X \rightarrow \chi_{c0} + 2\pi^0)$, eV	63.3 Z_D (58.2)	94.0
$\Gamma(X \rightarrow \chi_{c1} + \pi^0)$, keV	11.1 Z_D (10.2)	16.4
$\Gamma(X \rightarrow \chi_{c1} + 2\pi^0)$, eV	743 Z_D (683.6)	1095.2
$\Gamma(X \rightarrow \chi_{c2} + \pi^0)$, keV	15 Z_D (13.8)	22.1
$\Gamma(X \rightarrow \chi_{c2} + 2\pi^0)$, eV	20.6 Z_D (19.0)	30.4

Note that explicit numbers refer to a binding energy of 0.3 MeV with the probabilities taken from Eq. (7). The decay pattern of Table 3 involving pions and χ_{cJ} states is sensitive to the leading molecular $(D^0 D^{*0})$ component. These predictions^[17] can serve to possibly identify the full hadronic composition of the $X(3872)$ in running and planned experiments.

5 $J/\psi V (= \omega, \phi)$ decays of $Y(3940)$ and $Y(4140)$

It was suggested in Ref. [30] that both the $Y(3940)$ and $Y(4140)$ are hadronic molecules. These hadron bound states can have quantum numbers $J^{PC} = 0^{++}$ or 2^{++} whose constituents are the vector charm $D^*(D_s^*)$ mesons:

$$\begin{aligned} |Y(3940)\rangle &= \frac{1}{\sqrt{2}} (|D^{*+} D^{*-}\rangle + |D^{*0} \overline{D^{*0}}\rangle), \\ |Y(4140)\rangle &= |D_s^{*+} D_s^{*-}\rangle. \end{aligned} \quad (9)$$

For the observed $Y(3940)$ and $Y(4140)$ states we adopt the convention that the spin and parity quantum numbers of both states are $J^{PC} = 0^{++}$. The coupling of the scalar molecular states to their constituents is again set up by the compositeness condition. To determine the strong $Y \rightarrow J/\psi V$ and two-photon $Y \rightarrow \gamma\gamma$ decays we have to include the couplings of $D^*(D_s^*)$ mesons to vector mesons (J/ψ , ω , ϕ) and to photons. The couplings of J/ψ , ω , ϕ to vector $D^*(D_s^*)$ mesons are taken from the HHChPT Lagrangian^[24, 25]. The leading-order process relevant for the strong decays $Y(3940) \rightarrow J/\psi \omega$ and $Y(4140) \rightarrow J/\psi \phi$ is the diagram of Fig.7 involving the vector mesons D^* or D_s^* in the loop.

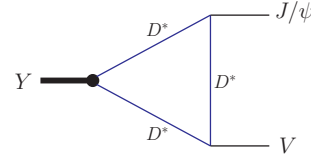


Fig. 7. Leading order diagram for $Y \rightarrow J/\psi V$ decay.

We also consider the radiative $Y(3940)/Y(4140) \rightarrow \gamma\gamma$ decay widths^[20], which serve as a prediction for possibly identifying the molecular structure of these Y states.

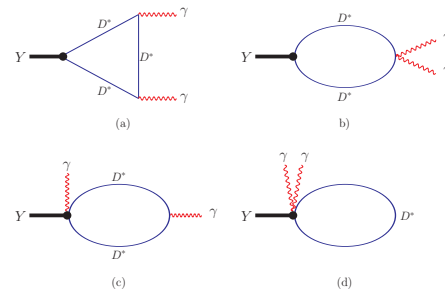


Fig. 8. Diagrams relevant for the radiative decay $Y \rightarrow \gamma\gamma$.

The relevant diagrams which arise from coupling of the charged $D^{*\pm}(D_s^{*\pm})$ mesons to photons and from gauging the strong interaction Lagrangian are displayed in Fig.8. The numerical results for the quantities characterizing the strong $J/\psi V$ ($V = \omega, \phi$) and radiative 2γ decays of $Y(3940)$ and $Y(4140)$ are contained in Table 4.

Table 4. Decay properties of $Y(3940)$ and $Y(4140)$.

Quantity	$Y(3940)$	$Y(4140)$
$\Gamma(Y \rightarrow J/\psi V)$, MeV	5.47 ± 0.34	3.26 ± 0.21
$\Gamma(Y \rightarrow \gamma\gamma)$, keV	0.33 ± 0.01	0.63 ± 0.01
$R = \frac{\Gamma(Y \rightarrow \gamma\gamma)}{\Gamma(Y \rightarrow J/\psi V)} \times 10^4$	0.61 ± 0.06	1.93 ± 0.16

The predictions of $\Gamma(Y(3940) \rightarrow J/\psi\omega) = 5.47$ MeV and $\Gamma(Y(4140) \rightarrow J/\psi\phi) = 3.26$ MeV for the observed decay modes are sizable and fully consistent with the upper limits set by present data on the total widths. The result for $\Gamma(Y(3940) \rightarrow J/\psi\omega)$ is also consistent with the lower limit of about 1 MeV^[11]. Values of a few MeV for these decay widths naturally arise in the hadronic molecule interpretation of the $Y(3940)$ and $Y(4140)$, whereas in a conventional charmonium interpretation the $J/\psi V$ decays are strongly suppressed by the Okubo, Zweig

and Iizuka rule^[11]. Further tests of the presented scenario concern the two-photon decay widths, which we predict to be of the order of 1 keV^[20]. Results for the strong J/ψ decays are quite similar for the $J^{PC} = 2^{++}$ assignment, which cannot be ruled out at this point.

6 Conclusions

The approach to hadron molecules based on the compositeness condition constitutes a consistent field theoretical tool. The determination of the decay properties of the open charm mesons $D_{s0}^*(2317)$, $D_{s1}(2460)$ and the hidden charm mesons $X(3872)$, $Y(3940)$ and $Y(4140)$ in comparison to present data is fully in line with a molecular interpretation of these states. We also give further predictions of decay properties which can be tested in future experiments. Current results are very encouraging in ultimately identifying hadronic molecules in the meson spectrum.

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